

6. SUMMARY AND CONCLUSIONS

6.1 INTRODUCTION

Results of toxicity testing, bulk sediment analysis, and bioaccumulation studies are presented in Chapters 3, 4, and 5, respectively. This chapter summarizes the results of each sediment testing component, and discusses the overall results of the combined testing program. The comprehensive results of the testing program provide information regarding the physical, chemical, and toxicological characteristics of the sediment and its potential effects if placed at the CODMDS.

6.2 BULK SEDIMENT CHEMISTRY

Results of the bulk sediment analysis are summarized by project reach in Table 6-1. Overall, the Charleston Naval Base berths exhibited the highest percentage of reference site exceedences for all analyte groups combined (24.6%). Sediments from the Charleston Naval Base berths also exhibited the highest percentage of reference site exceedences for trace metals and PAHs compared to the other three reaches. Trace metals were the dominant analyte group that exceeded the reference values for all sampling reaches.

The project samples represented the vertical composition of sediment proposed for dredging. The composited sediment cores contained proportions of surficial sediment (most recently deposited and most-likely to be contaminated) and historical sediment (deposited prior to industrial revolution and non-contaminated by anthropogenic sources). The portion of surficial and historical sediment in each sample varied and was dependent upon the depth of the core and the sediment volume required for the analyses, and the thickness of recently deposited sediment at the site. The proportion of surficial sediment potentially containing anthropogenic contaminants was likely less than 10% percent in any sample. The results of the bulk sediment analysis are consistent with the core composition, revealing primarily naturally-occurring trace metals and scattered detections of anthropogenic contaminants.

Reference sediment serves as a contaminant-free point of comparison to identify potential contaminant impacts for dredged material. Ideally, the reference sediment “is as similar as practicable to the grain size of the dredged material and the sediment at the disposal site” (EPA/USACE 1994). In this study, differences between bulk sediment results for the project reaches and the reference site are likely influenced by the difference in grain size composition. The reference site sediment from the disposal site was primarily sand (97%) and the project reaches were comprised of higher proportions of silt and clay particles (averaging 20% silt and 41% clay). In addition, the project reach sediments contained higher concentrations of TOC (average 2.8%) than the reference sediment (0.56%). Sediments in tidal river systems, such as those in the Daniel Island project reaches, are often characterized by high TOC and silt/clay content due to deposition of particulates that originate from erosion, land use practices, etc. Chemical contaminants adhere to sediment particles. Metals and organic contaminants may be adsorbed by organic materials that coat the surface of sediment particles (Eskin et al., 1994). Fine sediments (silt and clay) have a greater surface area per unit mass than coarse sediments, thus they have a higher potential for contaminant adsorption. Pesticides/PCBs, PAHs, dioxins, and furans are nonpolar organic chemicals that tend to occur in association with organic matter.

In well-oxygenated environments, metals to bind to organic matter and iron and manganese hydroxides (Luoma 1990). The differences in the chemical composition between project reaches and the number of analytes exceeding the reference site concentration may be explained, at least in part, by a grain-size/TOC effect.

6.3 TOXICITY TESTING

Results of the water column and whole sediment toxicity testing are summarized in Table 6-2. In water column tests, *Arbacia punctulata* was the most sensitive species to the project sediments, followed by *Menidia beryllina* and *Mysidopsis bahia*. Water column tests revealed low toxicity to *Mysidopsis bahia* for all project reaches. Only full strength elutriates from the Charleston Naval Base sediments were toxic to *Menidia beryllina*. LC50 values for *Menidia beryllina* exposed to the Charleston Naval Base sediments ranged from 30.0 percent to 75.4 percent elutriate. Elutriates from all project reaches caused effects in the *Arbacia punctulata* embryo tests. Embryo development for *Arbacia punctulata* was abnormal for organisms exposed to elutriates from all project reaches, with the exception of the reference sediment. For the water column toxicity testing, with the exception of CNB-01, CNB-02, and CNB-03, the results indicate that a dilution ratio of 4.3 to 5.7 fold would produce an LC50 value of >100 percent elutriate.

The evaluation of benthic-effects for whole sediment bioassays is based on the Limiting Permissible Concentration (LPC). The LPC is defined as "...that concentration which will not cause unreasonable acute or chronic toxicity or sublethal adverse effects based on bioassay results using...appropriate sensitive marine organisms..." (U.S. EPA/USACE 1991). The proposed dredged material does not meet the LPC if the mortality of the test organism (1) is statistically greater than mortality in the reference sediment, and (2) exceeds reference sediment mortality by at least 10 percent. A value of 20 percent reference exceedence is typically used for amphipod tests.

Whole sediment testing for the Daniel Island study indicated that none of the sediments were even moderately toxic to *Mysidopsis bahia*, although survival at several stations (CNB-01, CNB-02, CPB-01 and WDR-02) was statistically different from the reference by more than 10 percent. Results of whole sediment testing with *Leptocheirus plumulosus* revealed high mortality in the reference site sediment (93 percent mortality as compared to 100 percent survival in the laboratory controls). *Leptocheirus plumulosus* prefers fine grained sediments, and the high proportion of sand in the reference sediment may have negatively impacted survival. Because *Leptocheirus plumulosus* reference survival was low, the sample data was compared to the control data, rather than to the reference. The results indicated that only station CPB-03 differed statistically from the controls by more than 20 percent.

6.4 BIOACCUMULATION STUDIES

Prior to conducting the tissue analysis, TBP values were calculated to identify potential contaminants of concern. Since TBP values were low and infrequent, protocols for the analytical testing were modified through joint discussions with URS Greiner, U.S. EPA Region IV, and USACE-Charleston. Rather than conducting analytical testing on each of the five replicate

tissue samples for each station, one pooled sample (composited from the five replicates) for each station was analyzed for the contaminants of concern.

Because tissues from individual replicates were pooled and tested as one analytical sample, statistical analyses could not be conducted to identify differences in tissue concentrations among stations for each species or to statistically compare the tissue concentrations at each station against tissue concentrations at the reference site. Therefore, all comparisons for tissue data are numerical. The following bioaccumulation results are not stated with statistical significance or non-significance.

Results of the bioaccumulation studies with *Neanthes virens* and *Macoma nasuta* are summarized by project reach in Tables 6-3 and 6-4. Overall, contaminants were more bioaccumulative in *Macoma nasuta* than in *Neanthes virens*. Based on percent exceedences, metals were the most bioaccumulative analyte group for *Macoma nasuta*, and PCBs were the most bioaccumulative analyte group for *Neanthes virens*. Comparing results from the four project reaches, organisms exposed to the Charleston Naval Base sediments exhibited the highest number of reference exceedences for both test species.

In the bioaccumulation study, few contaminants were detected in tissues exposed to the reference sediment. Results for the project reaches revealed bioaccumulation of lead and zinc in *Neanthes virens* and bioaccumulation of lead, zinc, copper, and chromium in *Macoma nasuta*. For both species combined, however, trace metal concentrations in tissue were more than twice the reference value in only four of 264 possible cases. Cadmium, mercury, and tributyltin, three potentially bioaccumulative trace metals were not detected in the bulk sediment or tissue samples. All pesticides detected in tissue (5 cases for *Macoma nasuta*) were more than twice the reference value; and for both species combined, only three of 462 cases were more than twice the reference value for PCBs. Overall, PAHs were most bioaccumulative group of analytes, with 32 of 396 cases more than twice the reference value for both species combined. Of those 32 PAH exceedences, 7 cases exceeded the reference value by ten fold. Nine of 374 cases were more than twice the reference value for dioxins/furans for both species combined. Three of those nine cases exceeded the reference by ten fold. Overall, the detected dioxin and furan congeners had low TEF potency, were the least environmentally active and of least environmental concern of the target congeners. In *Neanthes virens* tissue, the maximum combined potency value (TEQ) of the dioxin and furan congeners was only equivalent to 0.1 ng/kg of total 2,3,7,8-TCDD. In *Macoma nasuta* tissue, the maximum combined potency value (TEQ) of the dioxin and furan congeners was only equivalent to 0.04 ng/kg of total 2,3,7,8-TCDD. None of the pesticides, PCB congeners, or dioxin/furan congeners that exceeded the reference tissue concentration were above the FDA Action Level or Tolerance Values.

The bioavailability of contaminants is dependent upon the chemical and physical characteristics of the contaminant and the characteristics of the sediment and the organism (Eskin et al.1994). Aquatic organisms may be exposed to the contaminants by direct ingestion of sediment or interstitial water or by direct physical contact with sediment or interstitial water. The bioavailability of trace metals is highly influenced by the presence of acid volatile sulfides which bind with divalent trace metals and causing them to become unavailable to aquatic biota. The bioavailability of pesticides/PCBs, PAHs, dioxins, and furans is dependent upon TOC. The results exhibited in the Daniel Island bioaccumulation study likely reflect bioavailability that is

influenced by a combination of the sediment grain size, the TOC content, and the test organisms. The reference sediment and project sediments were characterized by distinctly different grain size composition and TOC content. The test organisms differed by morphology and feeding modes.

6.5 CONCLUSIONS

The following conclusions are derived from the results of the Daniel Island Sediment Testing and Analysis Program:

- Bulk sediments were representative of the composition of the sediments proposed for dredging.
- The sediment proposed for dredging is predominantly (90 percent or greater) subsurface material deposited prior to industrial development that would not be expected to contain anthropogenic contaminants.
- The physical characteristics of the reference sediment and the project reach sediments were distinctly different. The reference sediment was predominantly comprised of sand and the project reach sediments were predominantly comprised of silt and clay.
- The project reach sediments contained higher concentrations of TOC than the reference sediment.
- Sediments from the Charleston Naval Base berths had the highest TOC content, had the highest percentage of total analytes exceeding the reference concentration, and had the highest percentage of metals and PAHs exceeding the reference concentrations of the four project reaches.
- The differences in chemical composition and number of analytes exceeding the reference site concentration for the project reaches may be explained at least, in part, by a grain-size/TOC effect.
- In water column tests, *Arbacia punctulata* was the most sensitive species to the project sediments, followed by *Menidia beryllina* and *Mysidopsis bahia*.
- The water column results indicated that a 4.3 to 5.7 fold dilution ratio would produce an LC50 value of > 100 percent elutriate for all species and all stations, with the exception of CNB-01, CNB-02, and CNB-03 for *Arbacia punctulata*.
- Elutriates from all project reaches were detrimental to *Arbacia punctulata* embryo development.
- Whole sediment testing indicated that none of the sediments were even moderately toxic to *Mysidopsis bahia*.
- In the whole sediment testing, only 7 percent *Leptocheirus plumulosus* reference survival was observed after the 10-day exposure period, as compared to 100 percent laboratory control survival. Grain size is hypothesized to be at least part of the reason for the poor reference site survival.
- Because *Leptocheirus plumulosus* reference survival was low in the whole sediment tests, the sample data was compared to the control data, rather than to the reference. The results indicated that only station CPB-03 differed statistically from the controls by more than 20 percent.
- Few contaminants were detected in tissues exposed to the reference sediment.

- Bioaccumulation studies revealed different results for the two test species, *Neanthes virens* and *Macoma nasuta*. Based on percent exceedences, metals were the most bioaccumulative analyte group for *Macoma nasuta*, and PCBs were the most bioaccumulative analyte group for *Neanthes virens*.
- Organisms exposed to the Charleston Naval Base sediments exhibited the highest number of percent reference exceedences for both test species.
- The detected dioxin and furan congeners had low TEF potency, were the least environmentally active and of least environmental concern of the target congeners.
- In *Neanthes virens* tissue, the maximum combined potency value (TEQ) of the dioxin and furan congeners was only equivalent to 0.1 ng/kg of total 2,3,7,8-TCDD. In *Macoma nasuta* tissue, the maximum combined potency value (TEQ) of the dioxin and furan congeners was only equivalent to 0.04 ng/kg of total 2,3,7,8-TCDD.
- None of the analytes that exceeded the reference tissue values in either test species were above the FDA Action Levels or Tolerance Values.